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## Stratigraphy and Paleontology of the Muroto Formation

By

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松本英二\*・寺嶋英志\*\*：室戸層の層序、貝化石および時代について

### Introduction

The Muroto district surveyed by the writers is located in the southern part of the Shimanto belt, the outermost major belt of Southwest Japan. The Shimanto belt consists of the complex of the Mesozoic and early Cenozoic geosynclinal deposits; the Mesozoic sediments tend to be developed in the northern part, and the early Cenozoic in the southern.

Detailed stratigraphy, geologic structure and age of the Shimanto complex are difficult to define, owing to the scarcity of reliable fossils for age determination as well as to the regionally monotonous rock-facies and complicated structures. But, some new facts on the geology of the Shimanto belt have been disclosed through the recent works in such provinces as southern Kyushu, southern Shikoku, southern Kii and southern Akaishi. The purpose of this paper is to present the stratigraphical succession and paleontological evidence of the Muroto formation, Shikoku Island, Southwest Japan (Fig. 1). The writers wish to express their thanks to Mr. T. YANO of the Muroto Junior High School, Muroto City, for his assistance in the field work.

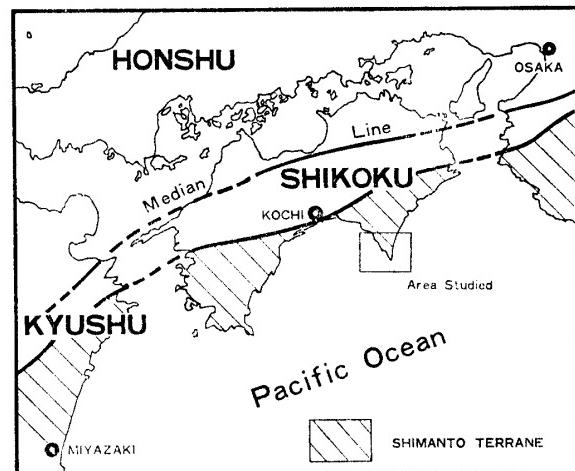


Fig. 1. General setting of the Shimanto belt.

### Stratigraphy

The present paper deals with the Muroto formation of SUZUKI (1930), KATTO *et al.*

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(1961), KATTO and ARITA (1966) and TERASHIMA (1967a, b), but the district surveyed does not cover the whole area of distribution of the formation. From the lithological and structural aspects, the writers divide the Muroto formation of the surveyed district into two members, Member A and Member B, in ascending order. Fig. 2 is a geological map of the Muroto formation in the area studied and Fig. 3 shows generalized columnar section.

Member A—This is the lower member of the Muroto formation developed in the area

Formation	Idealized Columnar Section	Thickness (m)	General Lithology	Fossils
Member B	Upper unit B <sub>2</sub>	500+	Muddy shale and mudstone with a small amount of sandstone and limestone nodule	<i>Periploma besshoense</i> <i>Liocyma furtiva</i>
	Lower unit B <sub>1</sub>	800+	Rhythmic flysch-type alternations of sandstone and shale; sandstone predominant	<i>Venericardia subnipponica</i>
Member A	Upper unit A <sub>2</sub>	800+	Rhythmic alternations of sandstone and shale, with some pyroclastics, sandstone predominant	<i>Pitar murotoensis</i>
	Lower unit A <sub>1</sub>	1,300+	Alternations of shale and sandstone, with basic igneous rocks and their pyroclastics, conglomerate and limestone	<i>Akebichoncha uchimuraensis</i> <i>Conchocele nipponica</i> <i>Lucinoma acutilineatum</i>

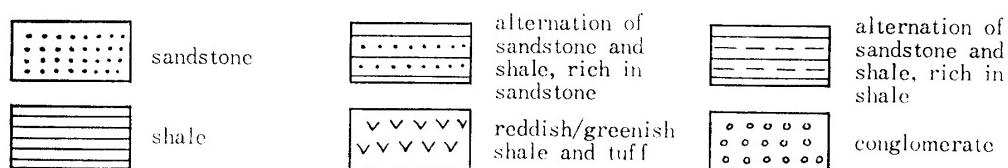


Fig. 3. Generalized geologic columnar section of the Muroto Formation.

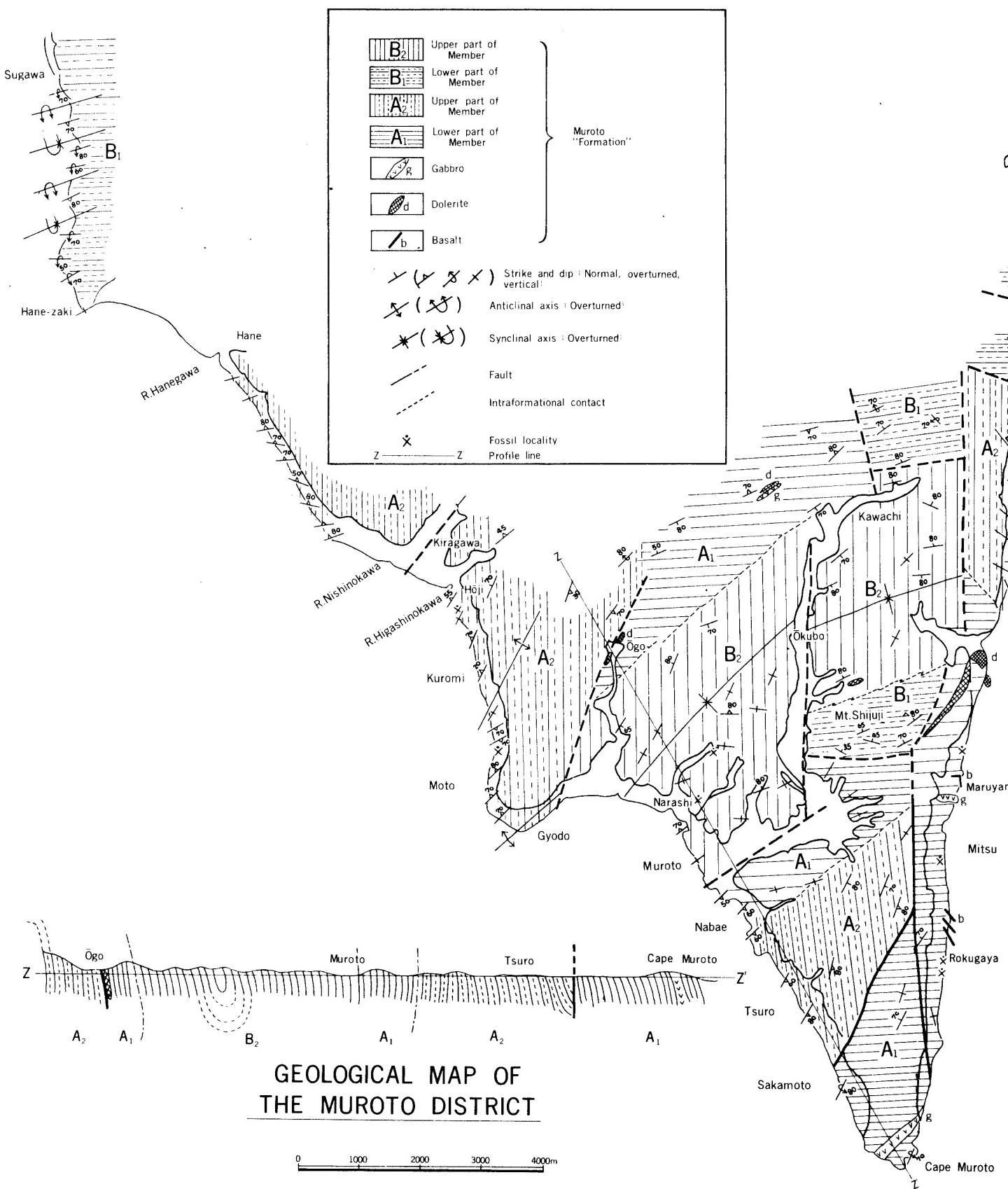


Fig. 2. Geological map of the Muroto district.

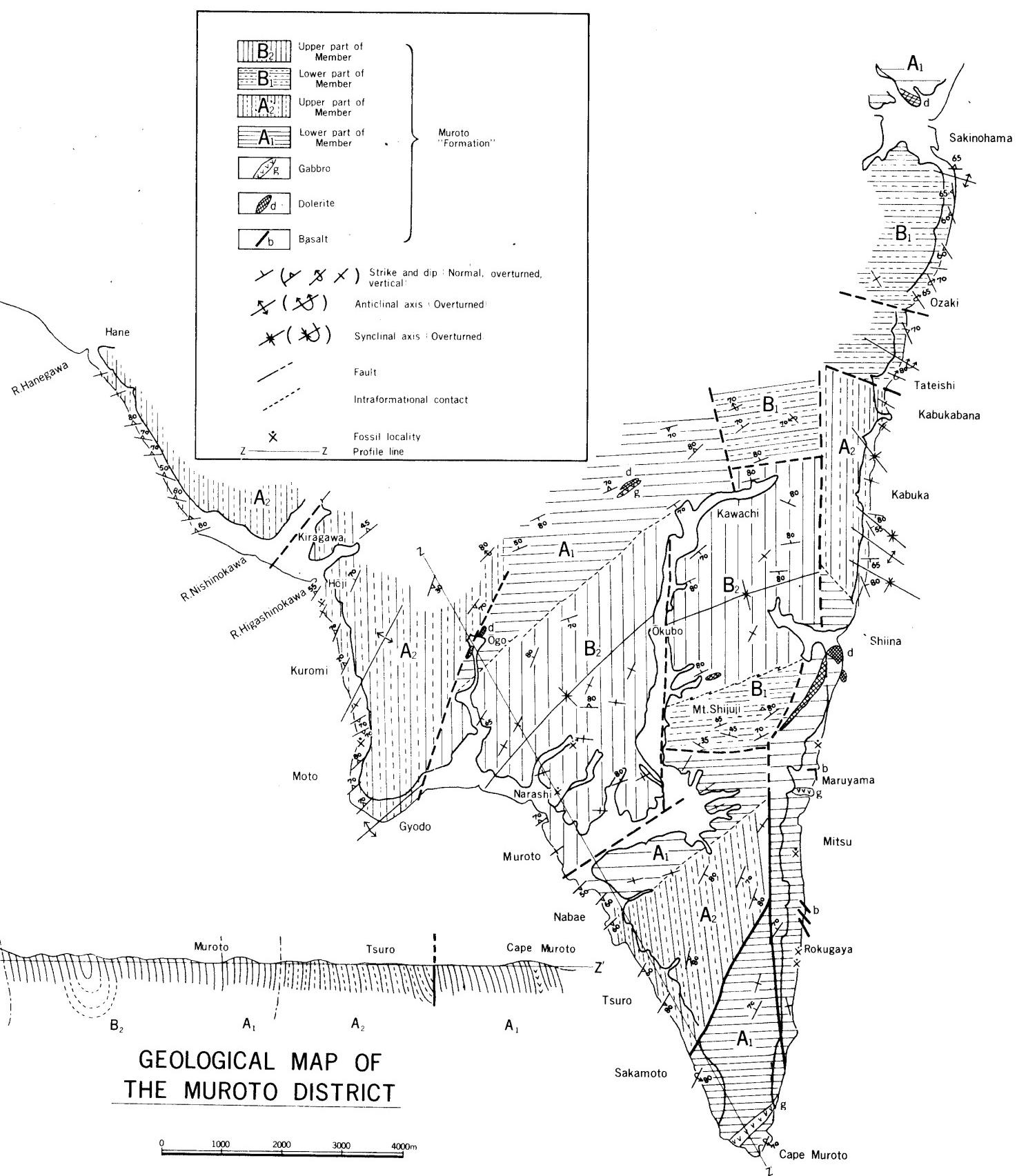


Fig. 2. Geological map of the Muroto district.

of the present report. By the lithological and stratigraphical features, Member A is subdivided into two stratigraphical units; A<sub>1</sub> in the lower part and A<sub>2</sub> in the upper part.

Unit A<sub>1</sub> is typically exposed along the west coast from the Cape Muroto to Sakamoto and also in the vicinity of Nabae, and its relation to the superjacent unit A<sub>2</sub> is conformable. Unit A<sub>1</sub> consists of rhythmically alternating shales and sandstones, intercalated with tuftaceous rocks and conglomerate. Shales are generally predominant over sandstones which are thinly bedded. In the north of Sakamoto reddish and greenish shales of considerable thickness are found; they grade into each other vertically and laterally. In the southernmost part of the Cape Muroto is found a conglomerate bed comprising pebbles of limestone, quartzite, sandstone and shale in a muddy matrix. The alternations resting on the conglomerate bed show conspicuous slumping, and the conglomerate bed seems to be of penecontemporaneous origin. In some horizons, limestone lenses are found. Unit A<sub>1</sub> is intruded by a dike of gabbro at the Cape Muroto. The total thickness of unit A<sub>1</sub> exceeds 1,300 m.

Strata corresponding to unit A<sub>1</sub> are distributed along the east coast from the Cape Muroto to Shiina, in the area between Kawachi and Ōgo, and also around the Shijujisan block. Unit A<sub>1</sub> exposed along the east coast is composed mainly of black shale, which is intensely deformed by folds and fault. In some horizons are found limestone lenses, containing molluscan fossils. A dike of gabbro intrudes the unit at Mitsu-Maruyama, and several dikes of basalt 1 to 3 m thick, intrude the unit in the area between Rokugaya and Maruyama. The strata in the area between Kawachi and Ōgo and in the area surrounding the Shijujisan block are composed of shales, intercalated with dolerite and pyroclastics. It is very difficult to clarify the stratigraphy and geological structure in these areas since most of the thin sandstones have been sheared into tectonic lenses.

Unit A<sub>2</sub> is typically exposed along the west coast from Sakamoto to the south of Nabae. It consists of flysch-type alternations of dominant sandstone and black shale. Sandstone layers are 5 to 30 cm, but sometimes several meters thick. In some places are found finely alternating sandstone and shale, each layer being thinner than 5 cm, where the sandstones are generally laminated (parallel, ripple and cross laminae), and often have sole marks at the bottom and ripple marks at the top of the beds. Sometimes slump structures with a width of several meters are observed. Unit A<sub>2</sub> in the type area is more than 800 m thick.

Member B.—The Member is the upper member of the Muroto formation developed in the area. From the lithological and stratigraphical point of view, Member B is also subdivided into two stratigraphical units: B<sub>1</sub> in the lower part, B<sub>2</sub> in the upper part.

Unit B<sub>1</sub> is typically exposed along the east coast between Sakinohama and Tateishi. It consists of alternations of sandstones and shales. The sandstones are far more predominant than the shale and are fine to very coarse, frequently fine-conglomeratic, containing patches of shales. The shale beds are thinner than 50 m. The formation ex-

posed in the type area is about 800 m thick.

The so-called Shijujisan formation which, after SUZUKI (1930), KATTO *et al.* (1961) and KATTO and ARITA (1966), is restricted to the vicinity of Mt. Shijujisan, can be correlated with unit B<sub>1</sub>. The strata found there consist of massive sandstone and flysch type alternations of sandstone and shale, and conformably underlie the unit B<sub>2</sub>. On the west coast, the strata between Hane-zaki and Sugawa are also correlated with unit B<sub>1</sub>.

Unit B<sub>2</sub> conformably lies on unit B<sub>1</sub>. It is exposed typically in the vicinity of the port of Muroto and composed of a series of muddy shale with occasional intercalations of thin sandstone. In some cases, it contains conglomerate layers which consist mainly of well-rounded granules of quartz, quartz shist, etc., 5 to 15 mm in diameter, and sandy matrix. The nodules of limestone or marl are sometimes found in the muddy shale. It is not possible to measure the precise thickness of the formation, but it is estimated at more than 500 m. The strata found in the area between Narashi and Ōkubo are correlated with unit B<sub>2</sub>.

### Sedimentary Feature

From the Shimanto terrane of Shikoku many sedimentary structures and marks were reported by KATTO (1959, 1961, 1964) and TERASHIMA (1967a, b). In the present study some of them are used as the means to determine the top and bottom of the bedding.

Three types of sedimentary structures and marks are found in the area; internal structures of bedding, marks on bedding surface, and penecontemporaneous sedimentary features.

Internal structure of bedding can be classified into three types; massive, laminated and graded. The laminated structure comprises ripple lamina, cross lamina and parallel lamina. The laminated and graded structures are sometimes very useful for top and bottom determination.

Marks on bedding surface have two types in origin, inorganic and organic. In the marks of inorganic origin, there are ripple mark found on the top of bedding plane and current and load casts (Fig. 1 of Pl. 7) found on the bottom of bedding plane. Among the marks of organic origin, problematic *Palaeodictyon* and trail of worms are remarkable. Problematic *Palaeodictyon* is marks with hexagonal cells and found in the sediments of various ages ranging from Triassic to Paleogene in the world. Marks of this type are found on the base of sandstone bed. Their origin remains unclarified, but it is considered to be, at least, of organic origin. In Japan the problematic *Palaeodictyon* also found in the Muro group in Kii, the Setogawa group in south Akaishi and in the Cretaceous strata of Hokkaido. In the Muroto formation, it is found in unit A<sub>2</sub> near Kuromi. Fig. 1 of Plate 8 shows the occurrence of *Palaeodictyon* associated with trails of *Nereites*. Various types of sole trails are observed on the undersurface of sandstone. (Fig. 2, 3, 4 of Pl. 8)

Four types of penecontemporaneous sedimentary structures are found in the area; convolute beddings, slump structures (Fig. 2 of Pl. 7), sandstone dikes (Fig. 3 of Pl. 7) and

submarine breccias. The sandstone dikes were discussed by TERASHIMA (1967b) in detail.

### Age of the Muroto Formation

It has been reported that distribution of the so-called Shijujsan formation is restricted to the vicinity of Mt. Shijujsan and the formation is characterized by massive sandstone and yields molluscan fossils of Upper Oligocene or Lower Miocene in age. The Muroto formation has been hitherto considered to unconformably underlie the Shijujsan formation, and has been assigned to Eocene (KATTO *et al.*, 1961, KATTO and ARITA, 1966).

MATSUMOTO and HIRATA (1972) reported the occurrence of *Akebichoncha uchimuraensis* and *Conchocele nipponica* from the Muroto formation and assigned their geological age to Upper Oligocene. They suggested that the Shijujsan formation might be equivalent to a part of the Muroto formation. YANO *et al.* (1974) reported the occurrence of *Venericardia subnipponica* from the sandstone bed at Narashi outside of the distribution area of the so-called Shijujsan formation, and assigned its geological age to Lower Miocene.

According to the present writers' subdivision of the formation, the fossils and their localities are classified as follows:

Member A:- KATTO *et al.* (1961) reported the occurrence of molluscan fossils such as, *Venericardia mandaica* (YOKOYAMA) in the conglomerate bed at the Cape Muroto and *Solemya murotoensis* KOBAYASHI in the black shale at Sakamoto. MATSUMOTO and HIRATA (1972) reported the occurrence of *Akebichoncha uchimuraensis* (KURODA) and *Conchocele nipponica* (YABE and NOMURA) which were collected from a limestone nodule at a point 1,500 m north of Mitsu. In the present survey, the writers collected *Lucinoma acutilineatum* (CONRAD) from a limestone nodule at a point 400 m south of Rokugaya. The above fossils indicate that Member A is assigned to Upper Oligocene, or more likely to Lower Miocene.

Member B:- According to MIZUNO (1956) and KATTO *et al.* (1961), the thick sandstone strata in the vicinity of Mt. Shijujsan which have been called the Shijujsan formation, yield the following molluscs: *Yoldia laudabilis* YOKOYAMA, *Portlandia watasei* (KANEHARA), *Volsella yamasakii* YOKOYAMA, *Venericardia elliptica* TAKEDA, *Turritella cf. chichibuensis* IDA, *Macoma cf. yamadai* NAGAO, *Lucinoma cf. actilineatum* (CONRAD), *Periploma cf. besshoensis* (YOKOYAMA), etc. They are indicative of the Upper Oligocene to the Lower Miocene and the strata which yielded them belong to the writers' Member B. YANO *et al.*, (1974) reported the occurrence of *Venericardia subnipponica* from the sandstone strata in the vicinity of Narashi which belong to the writers' Member B. The writers also collected several molluscan fossils from an outcrop of Member B in a brook 1.5 km northeast of Narashi. They are contained in nodules in the shale and identified as *Periploma besshoense* and *Liocyma furtiva*. Therefore, Member B, which includes the so-called Shijujsan formation, is also assigned to Upper Oligocene, or more likely to Lower Miocene in age.

To conclude, the whole succession of the Muroto formation here in question is considered to have been deposited during the Upper Oligocene or Lower Miocene time.

### Description of Molluscan Fossils

#### Family **Veneridae**

#### Subfamily **Pitarinae**

#### Genus **Pitar** RÖMER, 1875

#### **Pitar murotoensis**, n. sp.

(Pl. 9, figs. 5, 6, 7)

Holotype NSM-PM-5730

Type locality:- On the coast of Hōji, at a point 700 m southeast of River Higashinokawa, Kiragawa-cho, Muroto City.

Description:- Shell large for the genus, thick, trigonal oval in outline, rather inflated; inequilateral, the anterior side being less than one half the posterior; antero-dorsal margin short and excavated, the postero-dorsal about twice as long as the antero-dorsal margin, broadly arched, very gently sloping backward; ventral margin broadly convex; anterior end somewhat produced and narrowly rounded, the posterior end well rounded. Umbones small, high, prominent, pointed and curved inward and forward; lunule rather well defined, ovate in outline.

Surface ornamented with crowded, fine concentric incremental lines and irregularly spaced growth grooves;

Dimensions (in mm):-

Specimen	Length	Height	Thickness
NSM-PM-5730	100	77	48

Remarks:- The present species is characterized by that the shell is large, thick and trigonal oval in outline. *Pitar kyushuensis* (NAGAO), reported from Eocene to Lower Oligocene, is somewhat allied to the present species in form, but is distinguishable by the smaller and more rounded shell. *Pitar californiana* (CONRAD), reported from the Upper Eocene Cowlitz formation in Washington, is also of a similar form to the present species, but has smaller and more rounded shell.

Occurrence and horizon:- A single detached limestone nodule containing *Pitar murotoensis* n. sp. was collected on the coast of Hōji, at a point 700 m southeast of River Higashinokawa, Kiragawa-cho, Muroto City. Member A. Upper Oligocene or Lower Miocene.

Depository:- National Science Museum, Tokyo

## Subfamily Tapetinae

Genus **Liocyma** DALL, 1870**Liocyma furtiva** (YOKOYAMA)

(Pl. 9, figs 1, 2, 3)

1924. *Venus furtiva*, YOKOYAMA; Jour. Coll. Sci., Imp. Univ. Tokyo, Vol. **45**, Art. 3, p. 15, pl. 2, fig. 6.
1934. *Liocyma furtiva*, MAKIYAMA; Mem. Coll. Sci., Kyoto Imp. Univ., Ser. B, Vol. **10**, No. 2, Art. 6, p. 152, pl. 6, figs. 41–43, 45–48.
1955. *Liocyma furtiva*, HIRAYAMA; Sci. Rep. TKD., Sec. C, Vol. **4**, No. 29, p. 102, pl. 3, figs. 18–20

Occurrence and horizon:- Several ill-preserved specimens were collected from nodules at an outcrop in a brook 1.5 km northeast of Narashi, Muroto City. Member B. Upper Oligocene or Lower Miocene.

Depository:- National Science Meseum, Tokyo.

## Family Periplomatidae

Genus **Periploma** SCHUMACHER, 1817**Periploma besshoense** (YOKOYAMA)

(Pl. 9, fig 4)

1924. *Tellina besshoensis*, YOKOYAMA; Jour. Coll. Sci., Imp. Univ. Tokyo, Vol. **45**, Art. 3, p. 14, pl. 2, figs. 1–5
1934. *Periploma besshoensis*, MAKIYAMA; Mem. Coll. Sci., Kyoto Imp. Univ., Ser. B, Vol. **10**, No. 2, Art. 6, p. 153 (no fig.)
1955. *Periploma besshoensis*, HIRAYAMA; Sci. Rep. TKD., Sec. C, Vol. **4**, No. 29, p. 107, pl. 4, fig. 31
1962. *Periploma (Aelga) besshoense*, KAMADA; Tertiary Marine Mollusca from the Joban Coal-Field Japan., Palaeont. Soc. Jap. Spec. Paper., No. 8, p. 75, pl. 6, figs. 1–4.

Occurrence and horizon:- A single ill-preserved specimen was collected from a nodule at an outcrop in a brook 1.5 km northeast of Narashi, Muroto City. Member B. Upper Oligocene or Lower Miocene.

Depository:- National Science Museum, Tokyo.

**Conclusion**

1. On the basis of the general lithology, the Muroto formation developed in the area of the present report is devided into four units; A<sub>1</sub>, A<sub>2</sub>, B<sub>1</sub>, and B<sub>2</sub> in ascending order. Unit A<sub>1</sub> is composed of alternations of shale and sandstone, with basic igneous rocks

and their pyroclastics. Unit A<sub>2</sub> is composed of flysch type alternations of sandstone and shale. Unit B<sub>1</sub> is also composed of flysch type alternations of sandstone and shale. Unit B<sub>2</sub> is composed of mudstone with a small amount of limestone nodules.

2. From the molluscan fossil evidence, the Muroto formation of the surveyed area can be assigned to Upper Oligocene or more likely to Lower Miocene.

The so-called Shijujiyan formation (SUZUKI 1930, KATTO *et al.*, 1961) corresponds to unit B<sub>1</sub>. The existence of the previously supposed unconformity below the Shijujiyan formation is denied.

## 要 約

西南日本外帯に属する四国室戸地方には激しく構造運動を受けた室戸層が発達している。室戸層の地層は主としてフリッシュ型の堆積物より成っており、砂岩頁岩互層を主体にして塩基性火成岩およびその火山碎屑岩、礫岩、石灰岩などを挟在している。調査地域の室戸層は全体で 3,000 m を超えると推定され、主に堆積相に基づいて 4 層に分けられる。これらはすべて整合であり、最下位 A<sub>1</sub> は火成岩・火山碎屑岩を含む砂岩頁岩互層、その上の A<sub>2</sub> および B<sub>1</sub> は典型的に発達したフリッシュ型互層、最上位の B<sub>2</sub> は泥質相が優勢で石灰質團塊を含む地層である。室戸層はフリッシュ型堆積物に特有の堆積学的特徴および構造を示している。

室戸層はこれまで不整合的に四十寺山層の下にあると考えられてきた。しかし本研究において、新たに発見した化石および以前に報告されている室戸層各層準およびいわゆる四十寺山層から産出した化石を詳細に検討した結果、両層はともに上部漸新統あるいは下部中新統であることが明らかとなった。また野外においても、四十寺山層は、筆者らの B<sub>2</sub> に整合におおわれていることが明らかとなった。よって、いわゆる四十寺山層と室戸層との間にいると仮定された不整合は、その存在の根拠はないと考えられる。

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### Explanation of Plate 7-9

#### Plate 7

1. Flute casts showing the current direction from the south, Kabukabana, Muroto city.
2. Sedimentary packet of alternation of sandstones and shales in slump structure near Kuromi, Muroto City.
3. Sandstone dikes in shaly sediments south of Kiragawa, Muroto City.
4. Dolerite showing pillow structure south of Shiina, Muroto City.

#### Plate 8

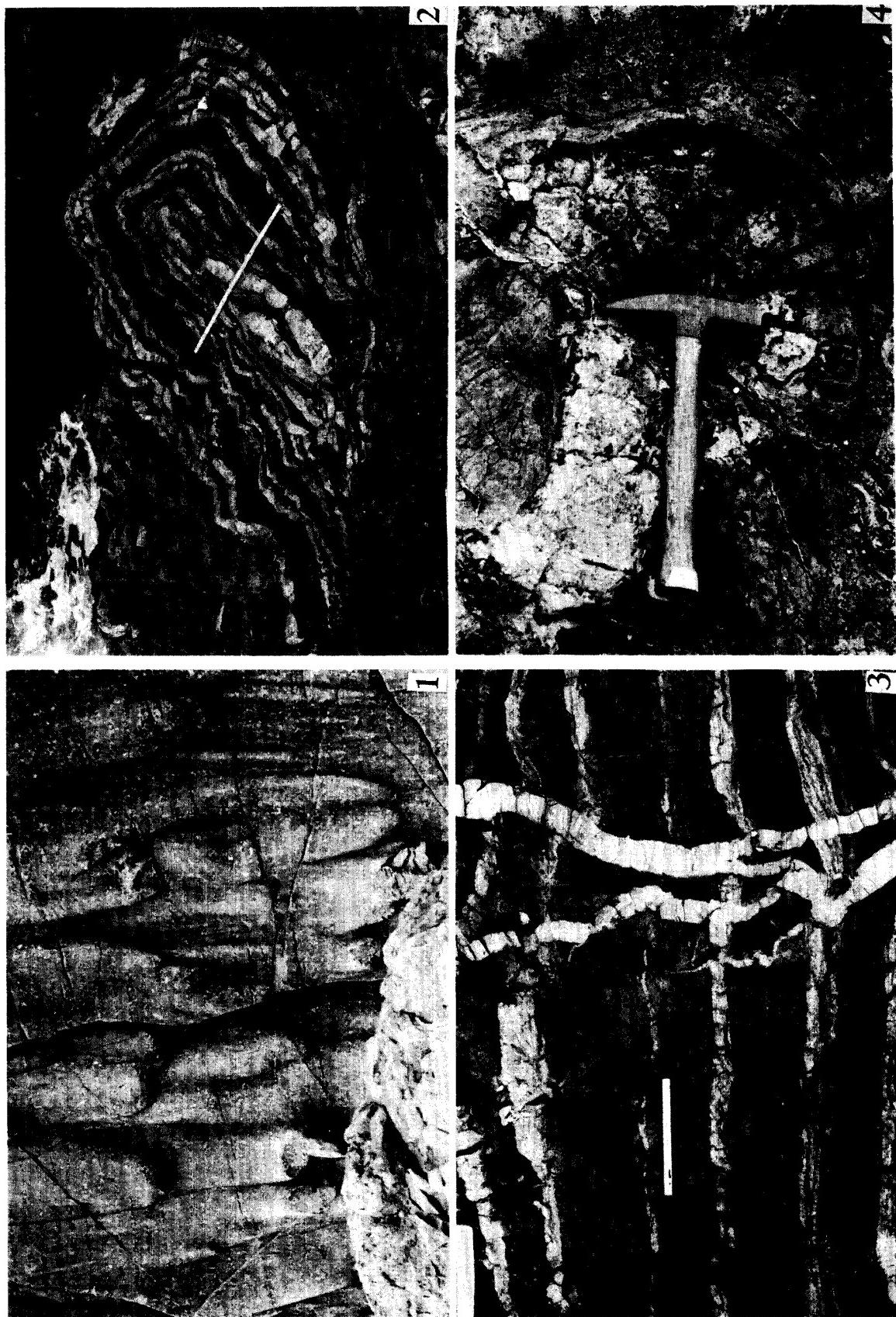
1. Trails of *Nereites* and *Paleodictyon* at Kuromi, Muroto City.
2. Trails of *Nereites*, south of Kabukabana, Muroto City.  $\times 1$
3. Trails of *Spiroraphe*, near Kuromi, Muroto City.  $\times 1$
4. Worm borings, near Hane-zaki, Muroto City.  $\times 1/2$

#### Plate 9

- 1, 2, 3. *Liocyma furtiva* (YOKOYAMA) Loc. 1.5 km northeast of Narashi, Muroto City.  $\times 1$ . Fig. 1, 2. Plaster model of external mould. Fig. 3. Internal mould.
4. *Periploma besshoense* (YOKOYAMA) Loc. 1.5 km northeast of Narashi, Muroto City.  $\times 1$ . Plaster model of external mould.
- 5, 6, 7. *Pitar murotoensis*, n. sp. Loc. on the coast of Hōji, at a point 700 m southeast of River Higashinokawa, Muroto City.  $\times 1/2$

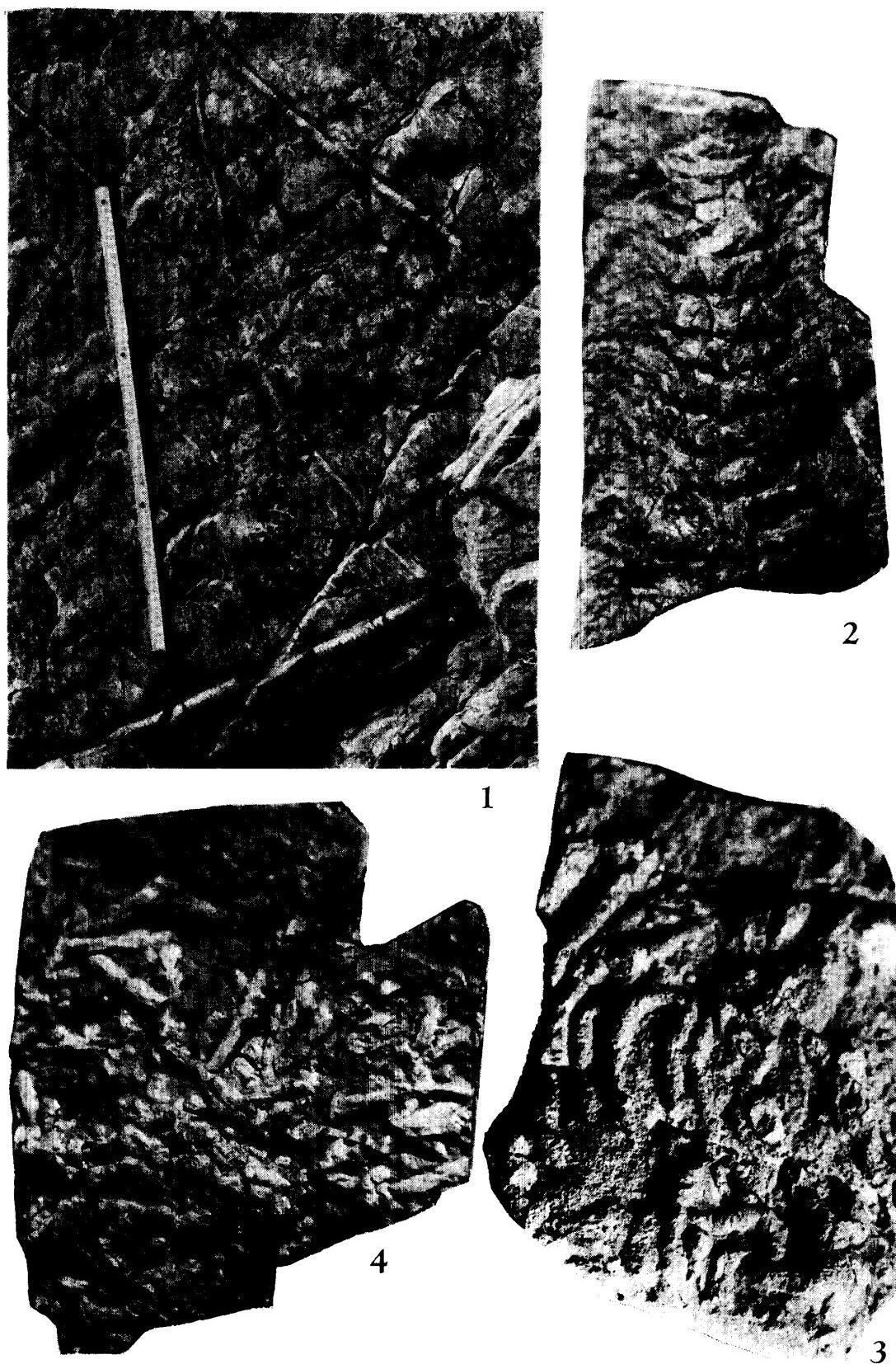
MATSUMOTO & TERASHIMA: Muroto Formation

Plate 7



**Plate 8**

MATSUMOTO & TERASHIMA: Muroto Formation



MATSUMOTO & TERASHIMA: Muroto Formation

**Plate 9**

